RECOVERY AND DELAYED MORTALITY OF PONDEROSA PINE AFTER WILDFIRE
FINAL REPORT PART I

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Final Report

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RECOVERY AND DELAYED MORTALITY

OF PONDEROSA PINE AFTER WILDFIRE[1]

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INTRODUCTION

In the wake of even the most severe fire there are a number of trees which are not killed outright but retain a portion of the crown unsinged. The health, vigor, and recovery of these trees may be important to the timber manager because it will determine trees to be salvaged (Connaughton 1936, Herman, 1954). A prediction of which trees will live is necessary for such trees will be a potential seed source for natural regeneration (Rietveld 1976).

A few studies have examined the delayed mortality in fire-damaged trees. Herman (1954) found that trees of sawtimber size which did not have 60% of more viable crown after a fire did not survive 6 years. In a study in Idaho, Connaughton (1936) found that 57% of the trees with less than 50% viable crown were dead after 3 years; compared to a 26% mortality of the trees which had over 50% of the crown remaining.

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As a result of a 15,000-acre man-caused conflagration in north-central New Mexico and a previous data base prior to the fire, it was possible to examine delayed mortality as well as recovery of ponderosa pine stands two growing seasons after a fire. Factors examined included previous fire history, stand density of living trees after the fire, crown damage, and competition of herbaceous vegetation.

THE STUDY

The La Mesa fire burned June 1977, consuming 15,270 acres of Bandelier National Monument, Santa Fe National Forest, and Department of Energy land of Los Alamos Scientific Laboratory. The study area is located on the eastern flanks of the Jemez Mountains in north-central New Mexico approximately 35 miles from Santa Fe, New Mexico. The area has a semi-arid continental climate with approximately 15 inches (38 cm) of precipitation per year.

The fire burned predominantly in the ponderosa pine zone; however, acreages within both pinyon-juniper and mixed conifer were flamed. Prior to the time of the fire, a fire ecology study was being conducted to determine the previous fire history of the area and the related plant succession (Foxx and Potter 1978). This provided baseline data so that after the fire it was possible to scrutinize the established plots and to determine the extent of damage to mature and reproductive ponderosa pine stock as related to previous fire history and phytosociology. In addition, plots in areas of light, moderate, and severe burn

damage were established immediately after the fire.

Soon after the fire, trees had been placed in six classes of foliar damage from nearly all the crown remaining to all needles having been consumed by the fire (fig. 1). The trees had been labeled with aluminum number tags. Fifteen months, or two growing seasons, after the fire each of the trees in these permanent plots were again re-examined to determine the improvement or decline in the foliar classification. Since the coloration of leaves killed by the fire was substantially different from those which had died subsequently, it was possible to include data concerning vigor of the tree as indicated by the needle condition. Height of the scorch and the presence of stump burn-outs, insects, mistletoe, and oozing of pitch were also noted. The amount of new growth within the scorched area was also determined.

RESULTS AND DISCUSSION

Improvement or deterioration of foliage condition in fire-damaged trees in relation to the following factors was examined: 1) extent of fire damage to the crown, 2) length of time since the area had burned prior to the La Mesa fire, 3) the density of living trees in the stand, 4) growth of herbaceous vegetation, particularly aerially seeded grass, and 5) various other factors such as beetle infestation.

General Condition

The analyses were based on a total of 897 trees in nine different plots all of which were in similar topography. Trees

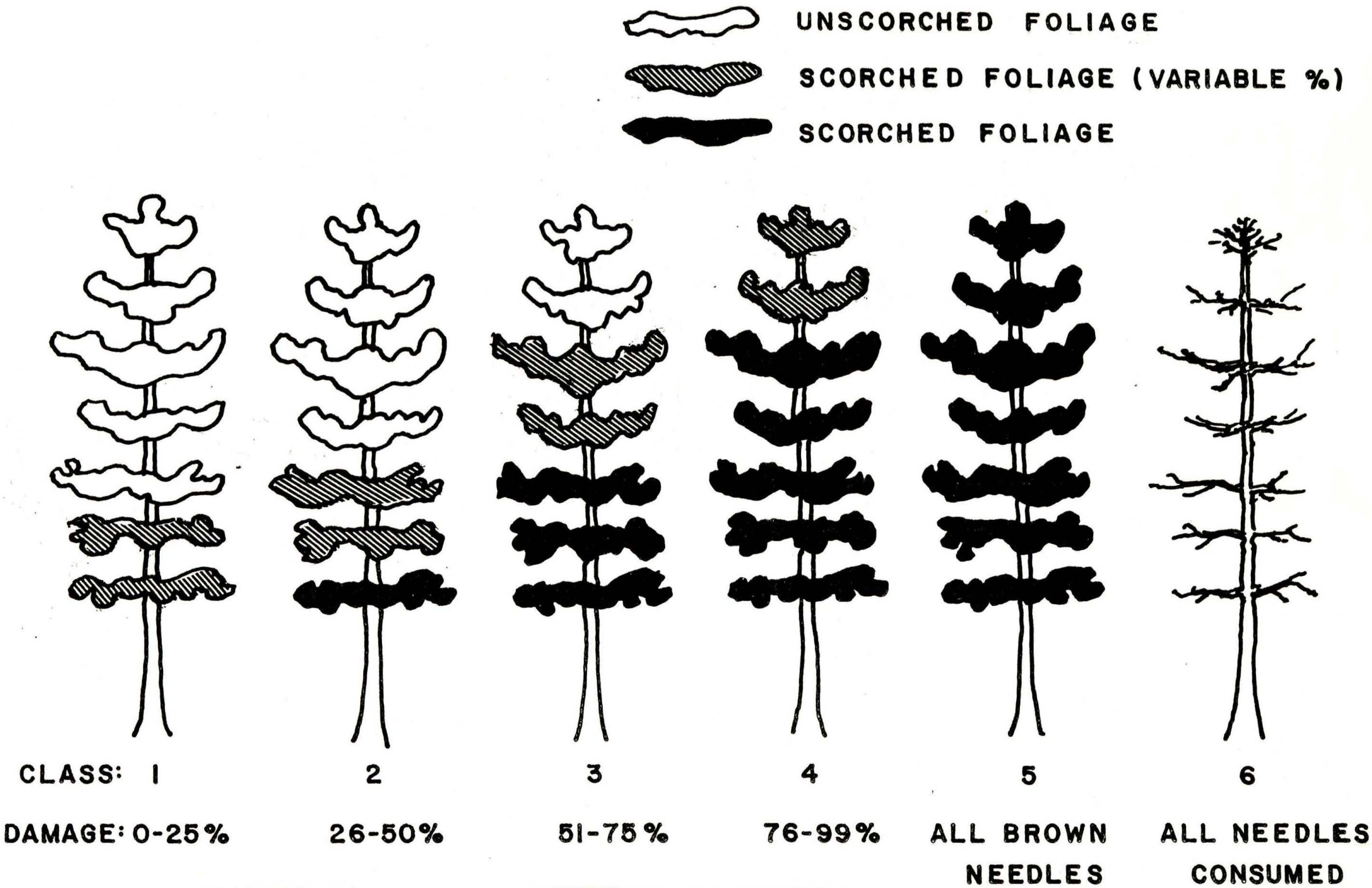

Figure 1. -- Classification of foliar damage.

in all size classes were included. Immediately after the La Mesa fire each tree within these plots had been placed in the various categories of foliar damage. Of the 897 trees examined soon after the fire only 606 were in class 1-5 or 68%. It was assumed then that trees within class 5 were dead because all needles were singed, dry, brown, and incapable of photosynthesis. This left only 393 trees with green needles or only 44% of the total population which were considered alive. Of those considered alive, only 148 (38%) had at least 50% of the crown remaining (classes 1-3), (Table 1).

In 1978, two growing seasons after the fire, 40% of the 897 trees were in class 1-4 and considered alive, a net loss of only 4%. Of the 354 trees which were living, 57% had over 50% of the crown viable, an increase of 55 trees (Table 1). Thus there was a net improvement from class 4 to classes 1-3 of 14% of the original population of 393 living trees. Of this population of living trees immediately after the fire, 90% were alive after two growing seasons, 10% had died.

Recovery Related to Foliar Damage Classification

Within two growing seasons after the fire there were some general trends. Trees with greater amounts of foliar damage showed an increasing mortality when compared with those in the less severely burned classes (fig. 2). In the various post-fire foliar damage classes the following percentages of trees were found to have improved or remained the same: class 1, 91%; class 2, 83%; class 3, 74%; and class 4, 83%.

Table 1. -- Comparison of condition of ponderosa pine immediately after the fire and after two growing seasons as determined by foliar damage classification

	Total	Trees Alive[1]		Trees Dead[2]		Trees with $50\%^{+}$ Living Crown[3]		
Year	Population	No.	% Total	No.	% Total	No.	% Total	% Living
1977	897	393	44	504	56	148	16	38
1978	897	354	40	543	60	203	23	57

[1]Trees in foliar damage classes 1-4.

[2]Trees in foliar damage classes 5-6.

[3]Trees in foliar damage classes 1-3.

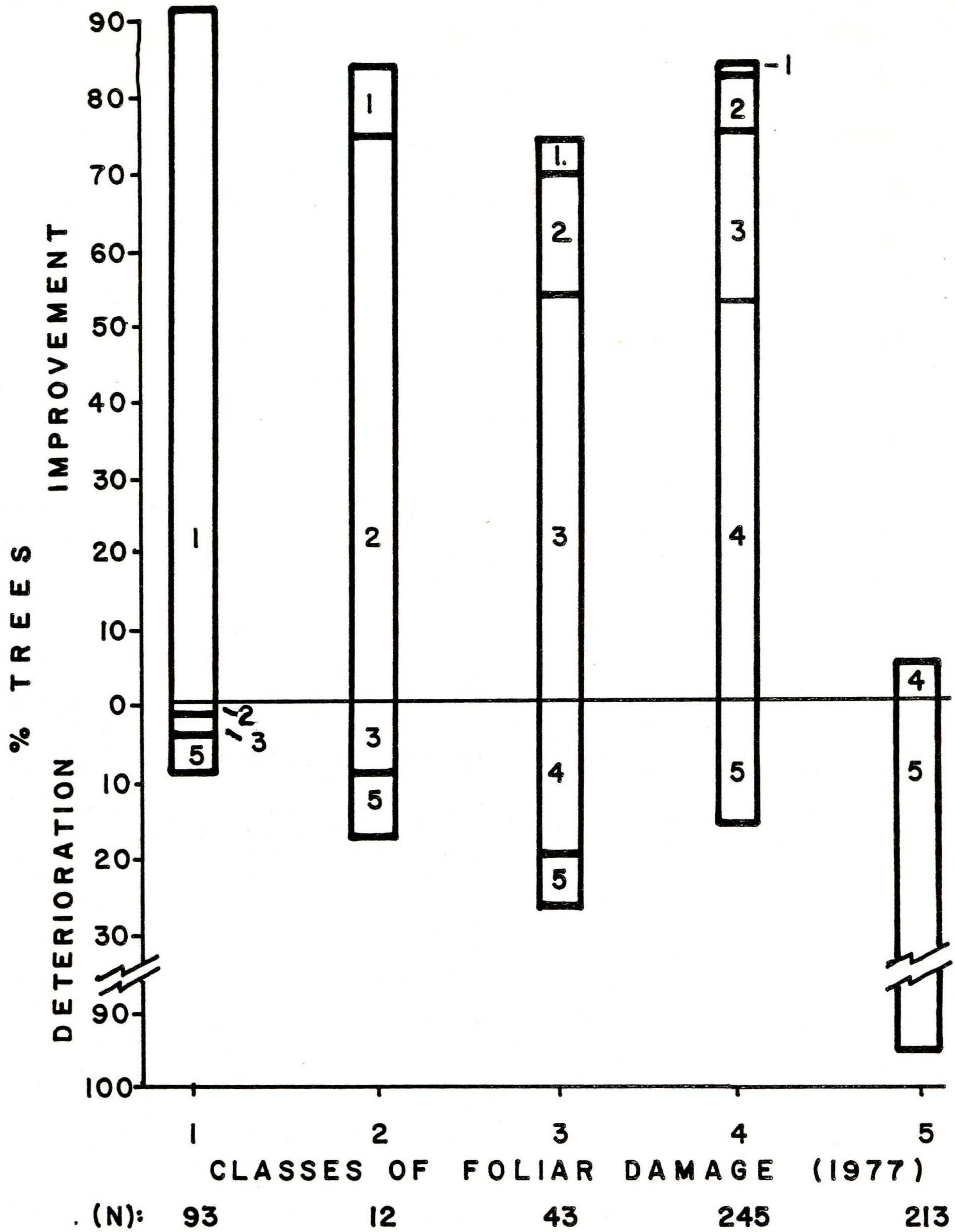

Figure 2. -- Changes in foliar classification after two growing seasons of all trees of all plots classified as 1-5 soon after the La Mesa fire.

Approximately 6% of the trees classified as having only brown needles (class 5) showed signs of recovery (fig. 2). This is because some small trees (less than 6 feet tall and 2 inches dbh) which had only brown needles after the fire, showed considerable recovery after two growing seasons (fig. 3). Young trees which recovered were in less dense stands. Trees of similar size in dense stands did not recover and, in general, more were severely scorched.

The exception to the general trend of recovery and foliar damage was the population of class 4 foliar damage (i.e., 76-99% foliage singed). These showed the greatest improvement as indicated by the largest percentage change to better foliage classifications. The population of trees in class 4 was examined in terms of the relative recovery of different size classes (fig. 4). The smaller size classes showed less improvement and greater mortality than trees in the larger size classes with the exception of trees within the 6 inch dbh class. Trees in this size class were found to be influenced by the density of the stand. Fourteen of the 31 trees within that class were in a lightly burned area which had 308 trees per acre as compared to other plots which had an average of 168 trees per acre. Thus, increased competition within the stand is thought to be the cause of the higher percentage of trees which deteriorated from class 4 to 5 and disrupted the general trend of less deterioration with increasing size class. For all size classes of the class 4 trees 26% improved, 54% remained the same, and 20% died.

A. B.

Figure 3. -- Comparative photographs of a small ponderosa pine soon after the fire which was classified as having foliar damage 5 with all needles singed and brown (A), and the appearance after two seasons with complete new growth of green needles (B).

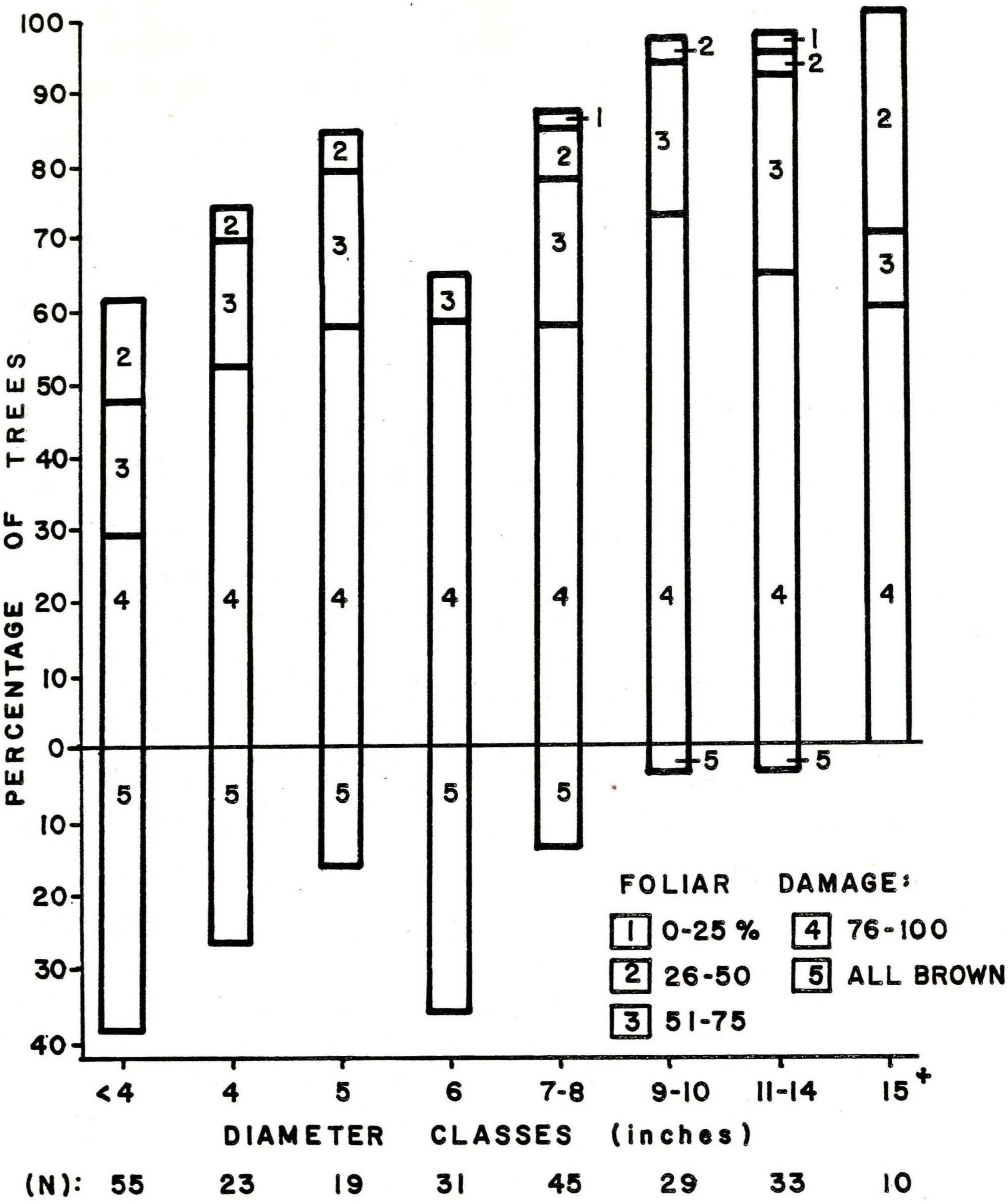

Figure 4. -- Changes in post-fire condition after two growing seasons of all 1977 trees of class 4 foliar damage by diameter classes.

Recovery of Damaged Foliage by Size Classes

We determined the amount of regrowth which occurred in two seasons within the foliage area previously scorched of trees in classes 1-4 and arranged this recovery by size classes of trees (Table 2). The total population of trees (357) was rather well distributed among the various size classes. Only 16% of the trees showed no recovery; 63% showed up to 25% of the damaged foliage with recovery; and only 3% of the trees showed 75-100% of the damaged area recovered. While the lack of any recovery appeared to be highest in the larger size classes of trees, it was the intermediate sized trees 5-8 inches dbh which showed the poorest response in the recovery of more than 50% of the damaged foliage. This degree of recovery was greater in the small trees 4 inches and less and in the large trees.

Recovery Related to Previous Fire History

Foxx and Potter (1978) found that the severity of damage to the overstory within the La Mesa fire was dependent on the length of time since the area had previously burned. We found that there was an increasing amount of foliar damage with the length of time since the area last burned (fig. 5). Based on the estimates of Herman (1954) that all trees which did not have at least 50% of the crown would eventually die, the foliar damage data was converted to an anticipated survival curve and arranged by the length of time since the area had been previously burned (fig. 5). The anticipated survival under this criteria was nil for trees in stands which had not previously burned

Table 2. -- Percentage of trees living after two growing seasons, by diameter (dbh) classes, having varying percentages of the previously singed foliage recovered as indicated by new growth

dbh	Total living trees (classes 1-4)	Categories of percent of singed foliage with regrowth				
		0	1-25	26-50	51-75	76-100
<4	72	14%	61	18	4	3
4	23	4	70	22	4	0
5	29	17	69	14	0	0
6	43	9	77	14	0	0
7-8	61	16	61	18	3	2
9-10	42	19	55	14	5	7
11-14	50	22	64	4	2	8
15+	37	22	53	11	11	3
Total	357	16	63	14	4	3

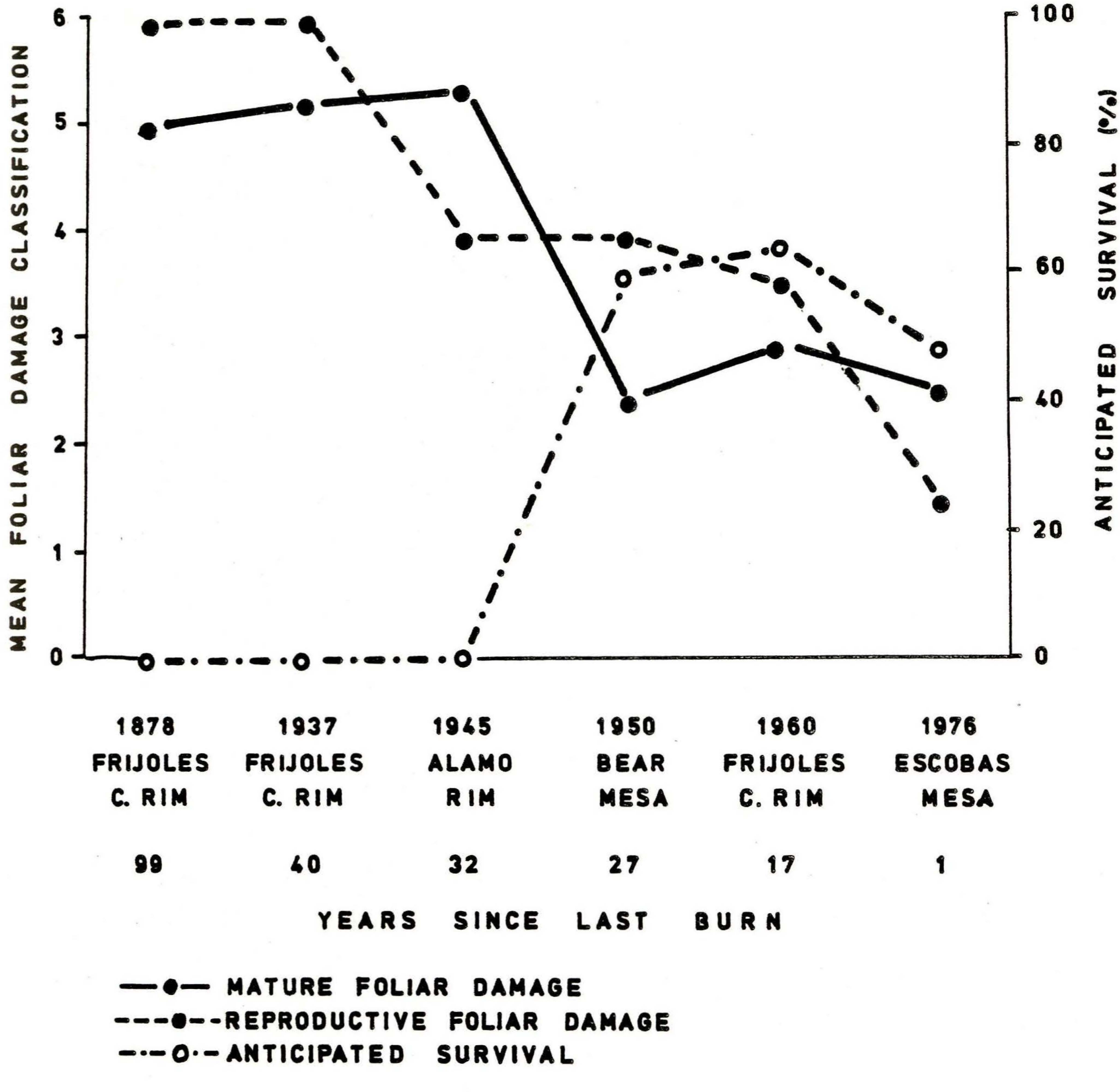

Figure 5. -- Foliar damage after La Mesa fire and the anticipated survival.

within the last 27 years. The average natural fire frequency at Bandelier before control was 18 years (Foxx and Potter 1978).

Examining the trees in these areas fifteen months later (two growing seasons), it was found that the actual survival at that time was higher than the anticipated survival (fig. 6). This was due to at least 2 factors: 1) the large number of trees within class 4 (76-99% foliar singeing) which remained the same or showed recovery, and 2) the openness of the 1945 site where many of the small trees which had less than 25% of the crown remaining recovered substantially. These trees were expected to succumb because they had less than 50% of the crown intact.

Recovery Related to Density

Figure 7 indicates the percentage change in foliar classification for the living trees in nine stands as related to the density of the stand. Trees in the least dense stands show a better recovery. Density is a definite factor in recovery where there were 130 trees or less per acre. However, as the density increases other factors such as the lightness of the burn, fuel loads, and competition with herbaceous vegetation can affect recovery. The apparent discrepancy in the recovery trend in stand 2 is related to pre-fire stand density. This stand had over 900 trees per acre and nearly complete kill of the trees. This left a low population of living trees. Due to the severity of the damage it is expected that root damage and cambium baking would impair the recovery of the few trees left in the stand. In contrast, stands 1 and 3 were relatively open stands prior to the La Mesa fire, thus the better recovery. The greater percentage

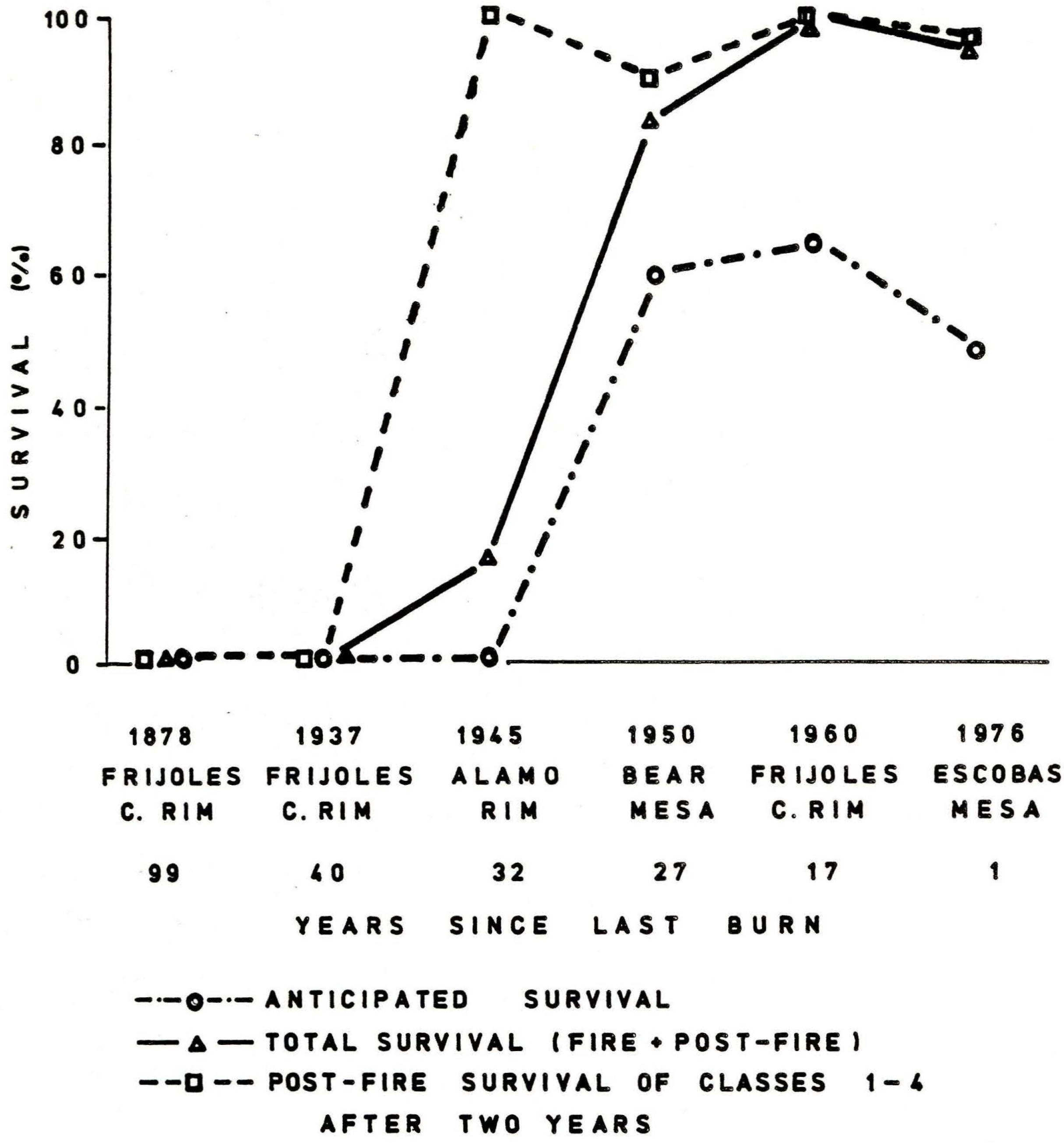

Figure 6. -- Anticipated survival of post-fire living trees and actual survival of all living trees and those in classes 1-4 after two growing seasons.

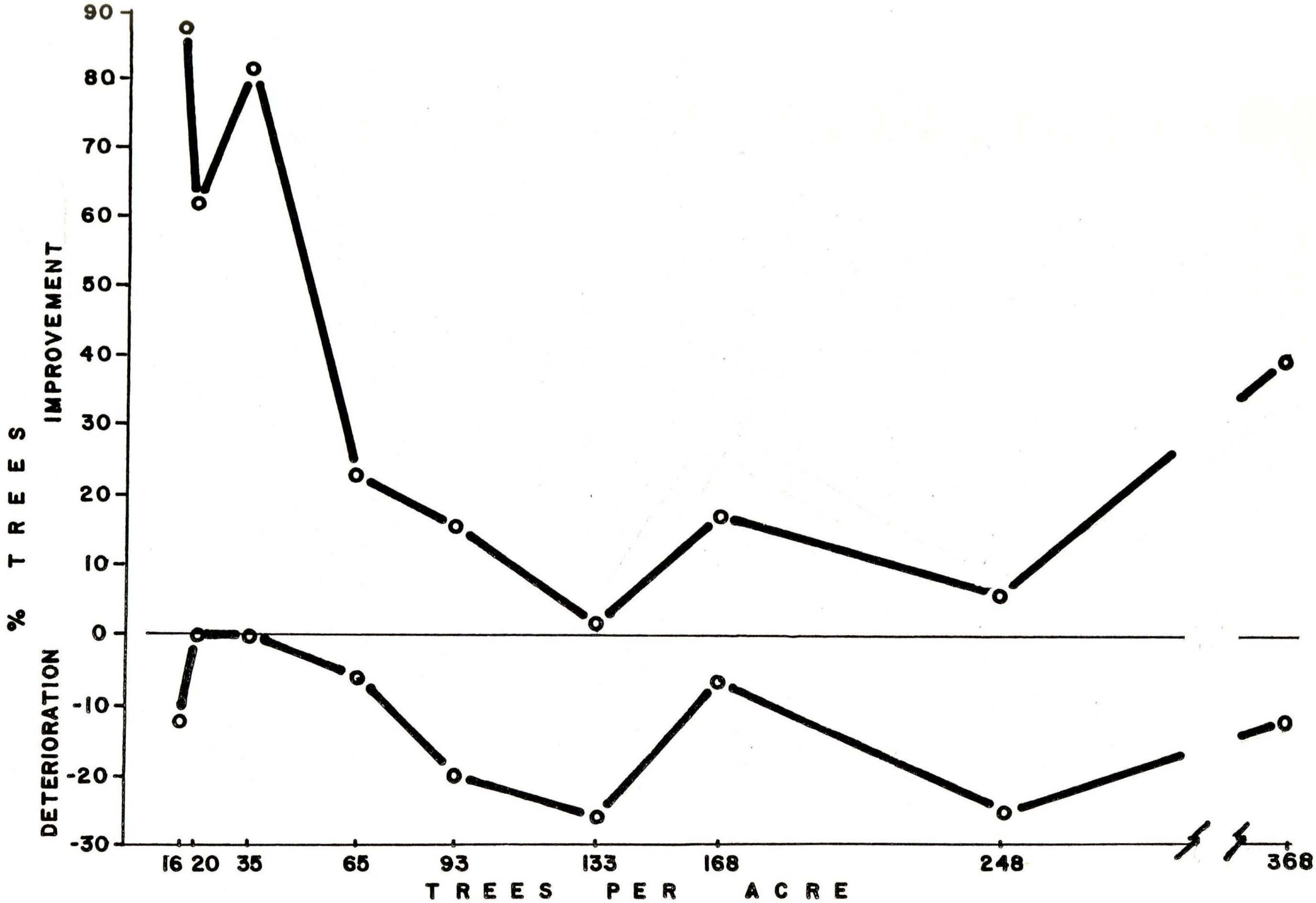

Figure 7. -- Percentages of change in foliar classification of all trees living after the La Mesa fire as related to density of living trees.

of recovery seen in plots 7 and 9 is also due to the pre-fire history. These plots had been burned over lightly one year prior to the La Mesa fire and in 1977 had fuel loads of only 1.3 tons/acre. Therefore, even though the stands were dense damage was not as great, and recovery was favorable even at these densities.

The influence of density as related to trees less than 4 inches dbh versus those over 4 inches dbh is illustrated in figure 8. Among immature trees less than 4 inches dbh there is 100% improvement of all trees until the density exceeds 94 trees/acre. At 130 trees/acre and greater there is a very small percentage improvement. The effect of increased density over 130 trees is more dramatically demonstrated for the curve in the decline of foliar classification. As the density increased, there is a greater percentage in a deteriorating condition which one would expect to continue to mortality. When one examines mature trees over 4 inches dbh there is illustrated a progressive negative influence on recovery as the density increased from 16 to 133 trees/acre. The two discrepancies in the curve at the greater densities have been explained in the discussion of figure 7.

When plots of known fire history were examined there was no strong relationship between recovery or decrease in foliar classification and the years since the area had burned previous to the La Mesa fire, or to the fuel loadings (fig. 9). However, there was a strong relationship between improvement or lack of

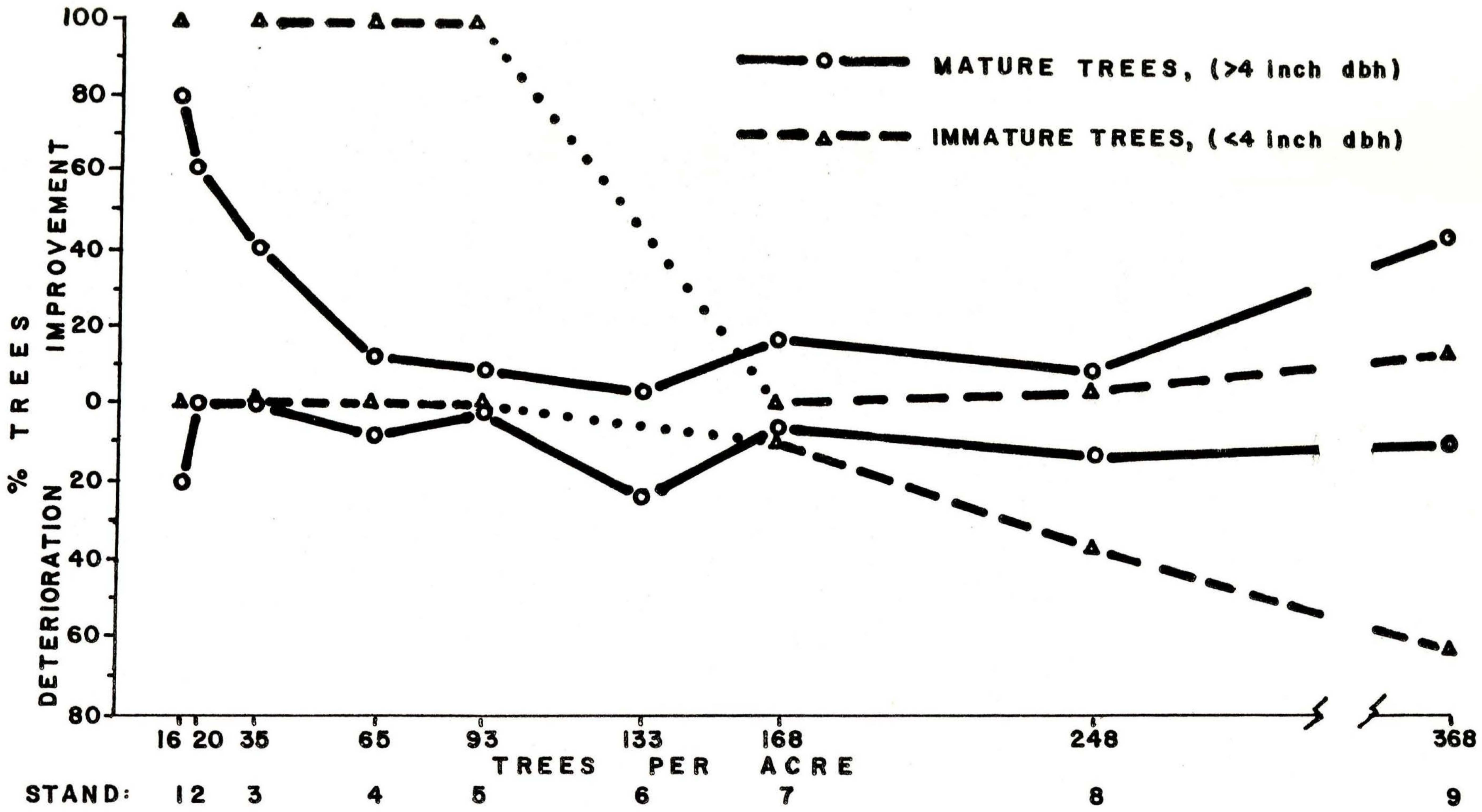

Figure 8. -- Percentages of change in foliar classification of mature versus immature trees living after the La Mesa fire as related to density of stand.

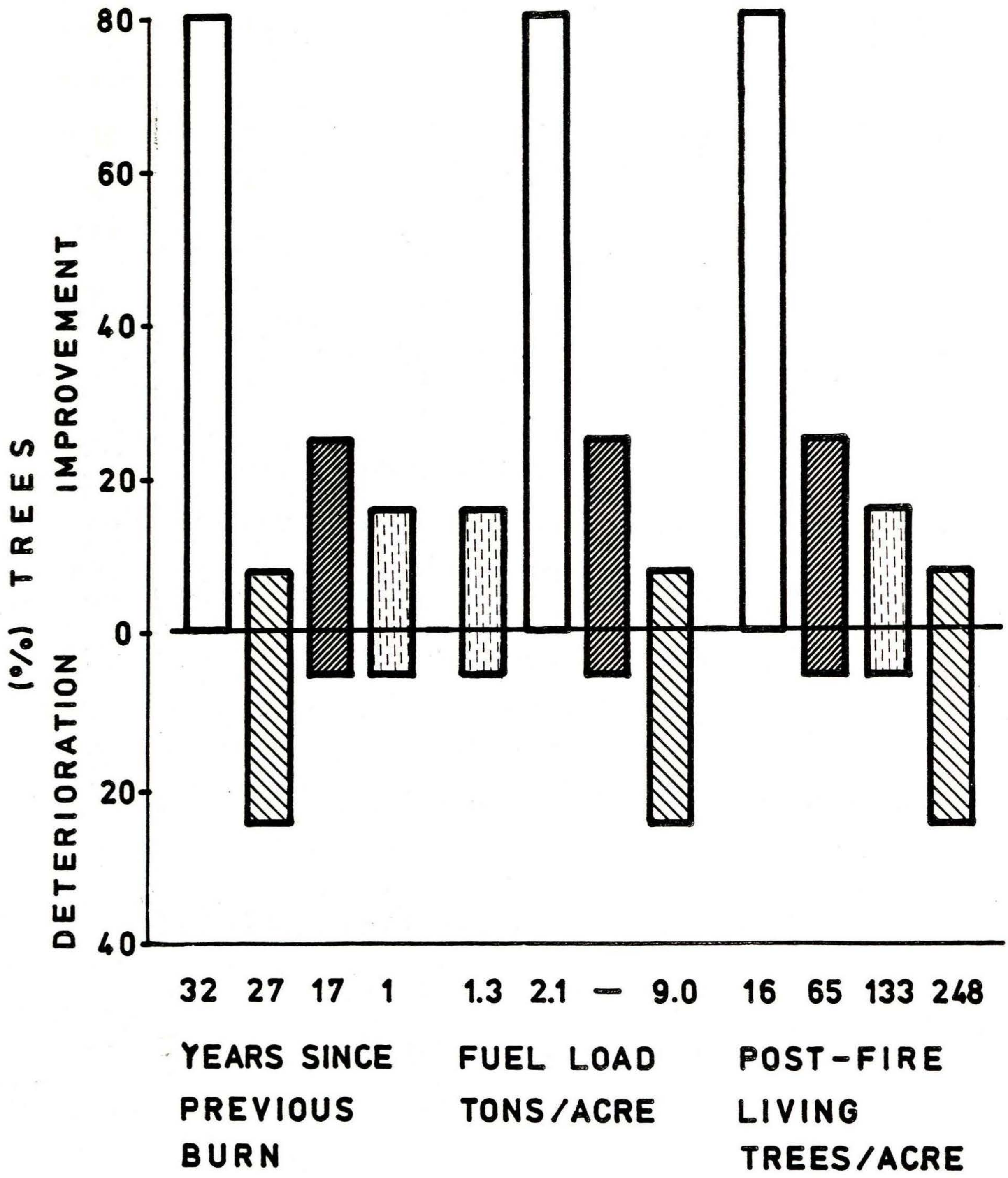

Figure 9. -- Percentages of change in foliar classification of living trees in stands of known fire history as related to length of time since the previous burn, fuel loads, and density of stand.

improvement in the damaged trees and the density of the stand. It can be seen that trees in the plots which were the least dense and had low fuel loads (mostly flash fuels) showed the maximum percentage improvement. In plots where fuel loads were low due to a fire one year previously, and the stand was dense, recovery was also good. However, the stand with the highest density had the highest fuel load, a combination which resulted in the lowest percentage improvement and the highest decline.

Recovery Related to Grass Competition

A factor which seems to affect recovery in one stand (stand 6) was the herbaceous cover, particularly the grass which was seeded soon after the fire for erosional control, (fig. 10). The highest cover of seeded grass occurs at the lowest point of improvement in foliar classification. We believe that the rapidly growing seeded grass is competitive with the trees for moisture and nutrients and is a causative factor in the poor improvement of this stand. Other stands having as great or greater herbaceous cover, most of which was not seeded grass, do not show the same inhibitory effect on tree improvement.

Recovery Related to Other Factors

Another factor which affected the health and vigor of the tree population which survived the fire was the beetle infestation. There were two ways we attempted to determine the influence of insects on the tree population. The first was evidence of the relative number of beetles, either by noting entrance holes or seeing the insects. The second was evidenced by the

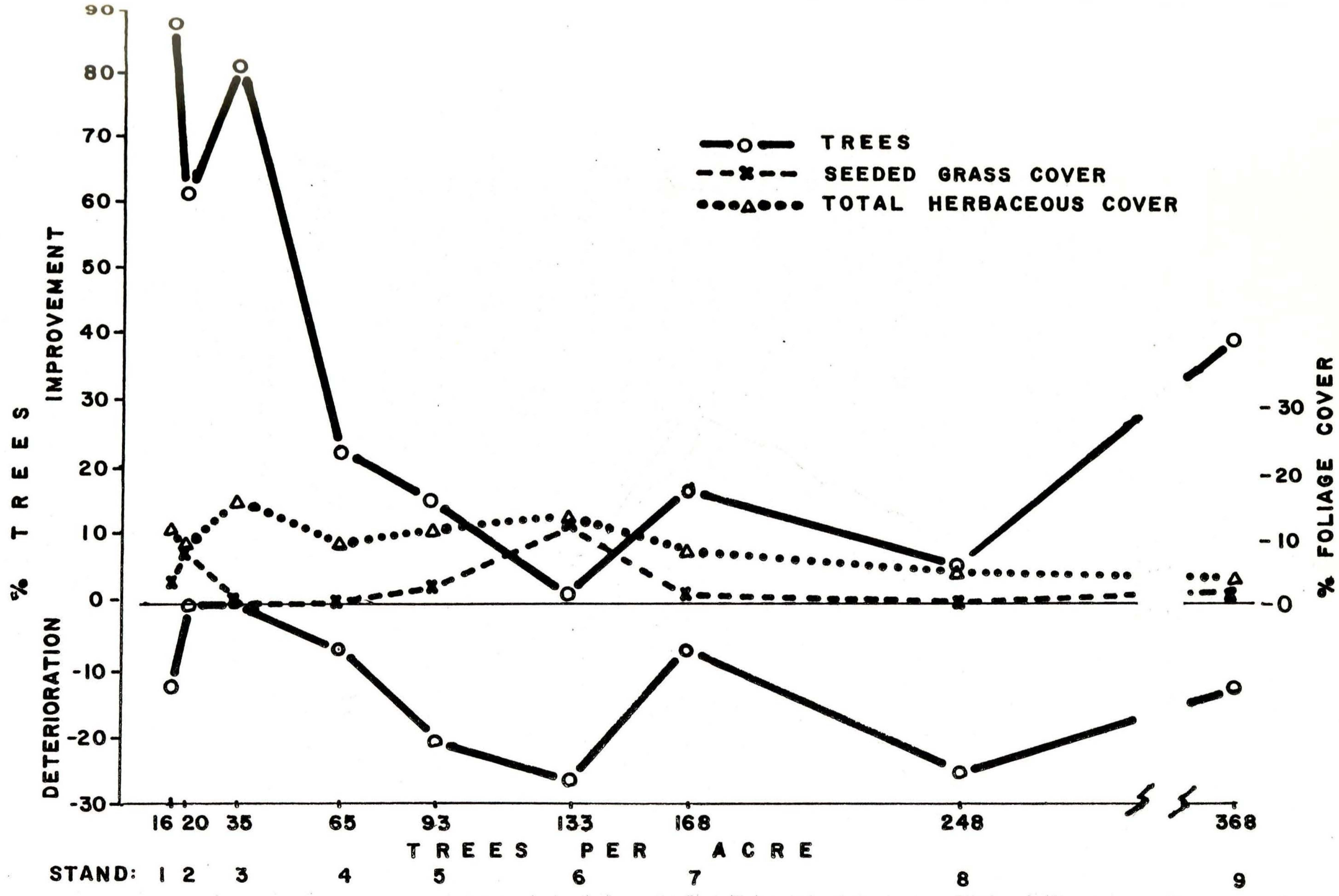

Figure 10. -- Percentages of change in foliar classification of trees living after the La Mesa fire as related to density of stand and competition with total herbaceous vegetation and seeded grasses.

amount of pitch produced by the tree. There was a negative relationship between the vigor as expressed by the color of the foliage of the tree and the insect invasion. Where there was considerable evidence of insect infestation the numbers of trees with a bright green, healthy color were less (fig. 11). There was a positive relationship between the exuding of pitch and the infestation of insects. We found that 12% of the 354 trees considered viable after the fire had direct evidence of insects. Over 40% of the viable trees were exuding pitch either as a negative or positive response to the damage by insects or the fire.

We found no relationship between the height of the scorching, presence of root burns, or disease conditions such as mistletoe with improvement or lack of improvement in the stands. We also did not find a relationship between the amount of regrowth within the scorched area within the first two growing seasons and factors such as crown damage, density, or insect infestation.

Conditions prior to and following each fire are quite different as are the conditions during the fire itself. In the recovery of a burned pine stand climatic conditions following the fire are important, especially precipitation and temperature. Drought may cause water stress in already stressed trees and contribute to delayed mortality.

The Pajarito plateau has summer monsoons. Thunderstorms occur almost daily beginning in early July and continuing into August. This is not the peak growing season for the pines but

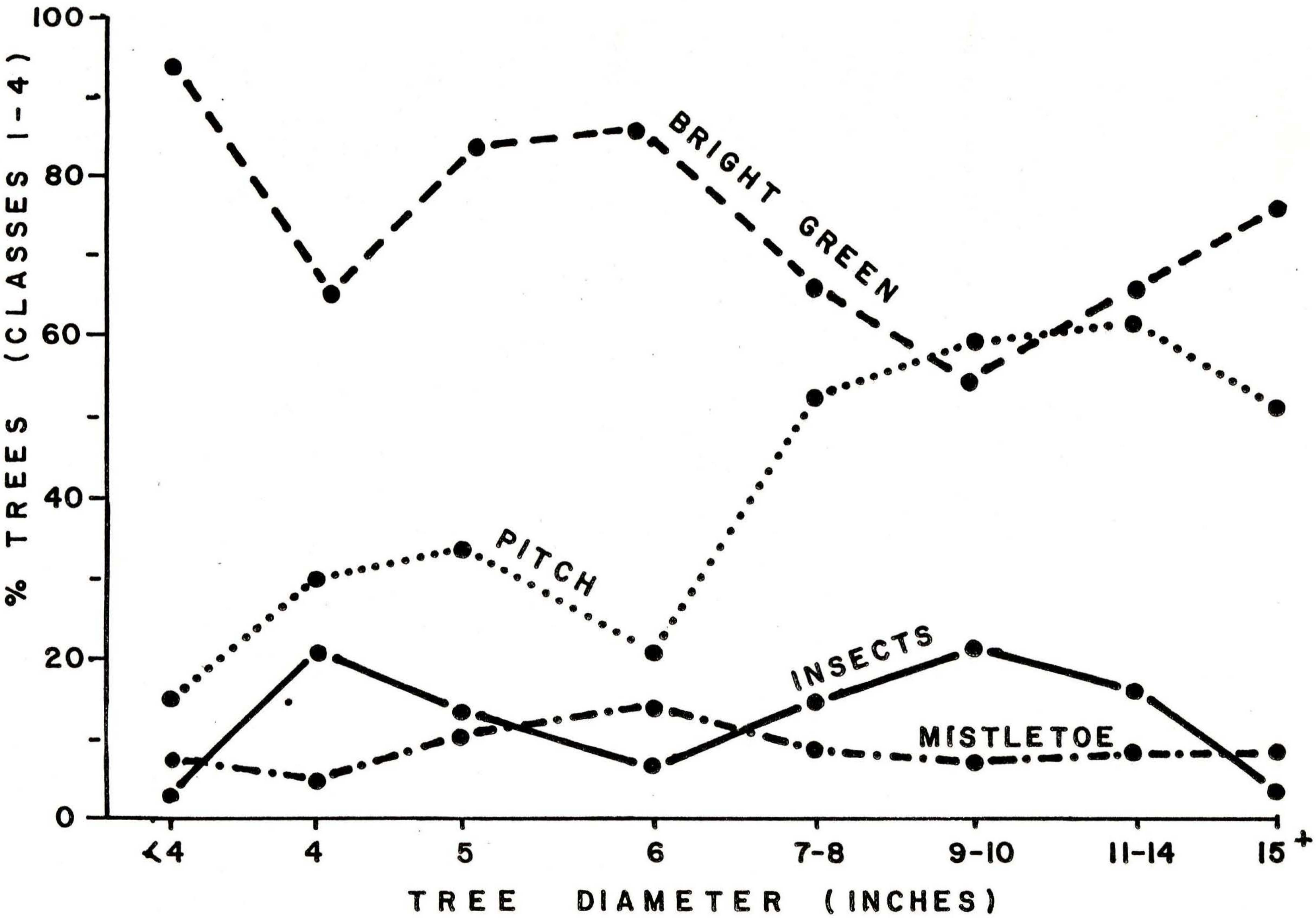

Figure 11. -- Vigor of living post-fire trees after two growing seasons as related to insect occurrence, pitch, and mistletoe.

moisture during this period is important especially to fire-damaged trees. The La Mesa fire occurred in late June 1977. The two months following the fire showed average to above average precipitation (fig. 12). During the second growing season, however, there was considerably less precipitation than normal. Temperatures during the winter months were not extreme. Thus, immediately after the fire there was not a drought condition which might have stressed the trees. Should the fire have occurred in late June of 1978, one would have expected a greater moisture stress and less recovery.

Continued Change in Condition

Cursory examination of the trees in several of the stands after the third growing period (September 1979) indicates that there has been some additional mortality. Practically all of the loss has been in trees of class 4 which in 1978 had not improved but had remained in that classification. Of a population of 150 class 4 trees in 1978 distributed in five different stands, an average loss of 14% in the third year has occurred. The other 86% of this population is very green and healthy in appearance, which might indicate that the peak of mortality is past.

Shrub Sprouting

The results of analyzing the sprouting of shrubs two seasons after the La Mesa fire are summarized in Table 3. These data were obtained by counting the number of clumps and sprouts in 20 plots of 0.01-acre size distributed across the area of the

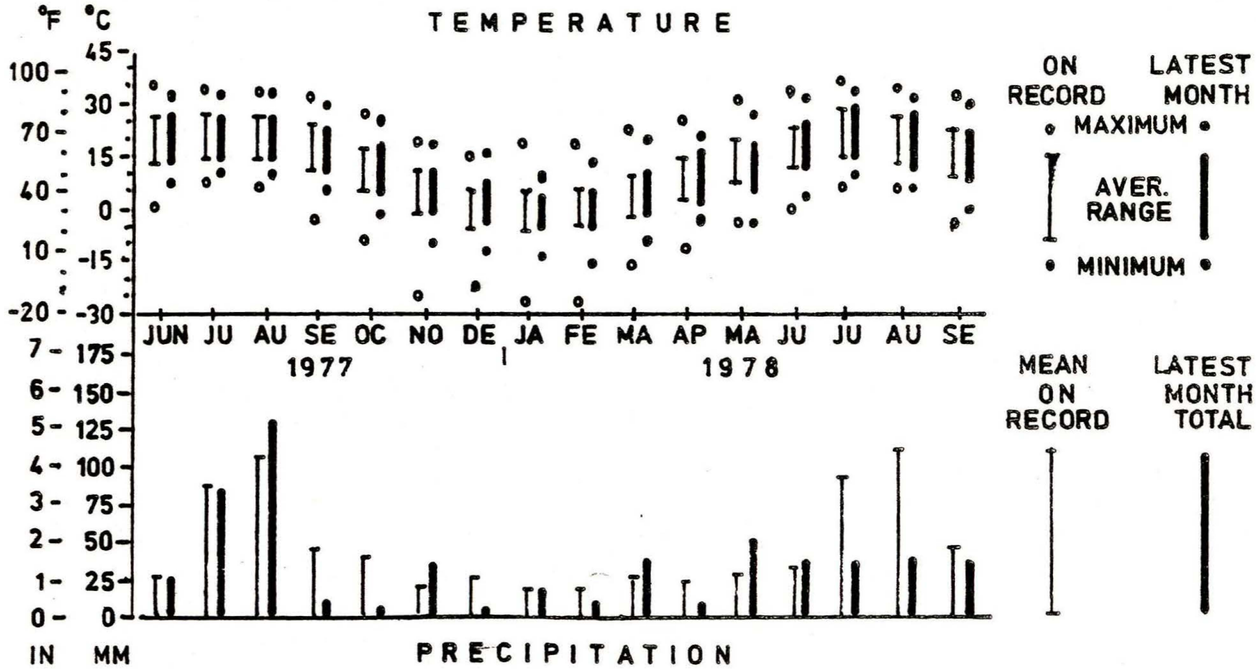

Figure 12. -- Weather summary for the 15 months after the La Mesa fire.

Table 3. -- Density of shrub clumps and individual sprouts per acre and average height

Stand	Species	Clumps /Acre	Sprouts /Acre	Aver. Height (cm)
Frijoles Rim	Cercocarpus montanus	70	75	38
1878 prev. burn	Quercus gambellii	395	1840	77
(Severe)	Robinia neomexicana	30	45	101
		495	1960	
Frijoles Rim	Ceanothus fendleri	15	20	52
1937 prev. burn	Cercocarpus montanus	20	130	62
(Severe)	Fallugia paradoxa	220	900	39
	Quercus undulata	40	505	75
		295	1555	
Frijoles Rim	Ceanothus fendleri	340	1790	42
1960 prev. burn	Quercus gambellii	180	2250	91
(Moderate)	Quercus undulata	50	645	59
	Robinia neomexicana	1535	2350	71
	Rosa sp.	35	60	25
		2140	7095	
Escobas Mesa	Fallugia paradoxa	10	20	26
1976 prev. burn	Robinia neomexicana	240	295	38
(Light)	Rosa sp.	50	50	25
		300	365	
Burnt Mesa	Ceanothus fendleri	45	85	48
dense stand	Cercocarpus montanus	5	20	83
(Severe)	Quercus gambellii	1355	5405	83
	Quercus undulata	15	55	90
	Rosa sp.	10	75	55
		1430	5640	
Burnt Mesa	Quercus gambellii	5	70	110
open meadow		5	70	
(Light)				

stand. The minimum number of clumps and sprouts occurred in the Burnt Mesa stand which was very open and meadow-like, having a good cover of grass which recovered quickly after the fire. The maximum number of clumps and sprouts occurred in the Frijoles Rim stand which had been previously burned in 1960. This stand was relatively open, the damage from the La Mesa fire was slight (most trees were in foliar classes 1-3). During the 17 years since the last fire the shrubs would have had time to become well established and the La Mesa fire was not severe enough to cause deep soil penetration of the heat and root kill. In contrast all of the trees in the Frijoles Rim stands previously burned in 1937 and 1878 were in foliar classes 5 and 6. Because of the greater severity of the fire root burnouts were much deeper, the soils were hotter, and there was greater root kill. Excavation of some roots indicated that only the lower side of some large roots remained viable from which sprouts were developing. The Burnt Mesa dense stand similarly revealed severe damage as all trees were in foliar classes 5 and 6 after the fire. It is suggested that a more rolling topography and perhaps a heavier soil resulted in less heat penetration and root kill as most of the sprouts were clumped around old charred trunk bases, which had been completely consumed in the severely burned Frijoles Rim stands.

The species Ouercus gambellii, Robinia neomexicana and Ceanothus fendleri are the dominants of the shrub cover.

CONCLUSIONS

Recovery of ponderosa pine after fire is complex. No single factor can account for the recovery or death of a particular tree. However, some ecological parameters may be more important than others. First, survival of fire-scorched trees is dependent on the severity of singeing. In some cases the destruction is such that the tree has no chance of recovery; in other cases conditions may be such that even a more severely damaged tree can have some growth response, particularly if the climatic conditions are favorable. We found that within the first two growing seasons after the La Mesa fire, trees with over 50% of the crown left undamaged showed a low percentage of mortality. Based on previous research, it was expected that trees with less than 50% of the crown left undamaged would all die within a short period of time after the fire. However, over 26% of these trees showed improvement, whereas 53% retained the same classification; thus, only 21% of these trees died in the two growing seasons. Of the trees in this severely damaged category, the smaller trees showed a higher rate of mortality than did the larger trees, although many saplings in open stands with complete singeing of needles, recovered completely. It is doubtful that severely singed trees which did not show an improvement of growth will be able to sustain themselves with the limited foliage present.

Density of the stand and the resulting competition influenced the recovery of trees, particularly those in the more severely damaged classes. These stressed trees were unable to compete for

water, nutrients, and light. There was a difference in the recovery as related to density of the stand in trees of different size classes (those over 4 inches dbh and those under 4 inches dbh). For the immature trees less than 4 inches dbh, stands of low density showed nearly complete recovery. However, in stands with over 133 trees/acre an increasingly high percentage of the young trees declined in vigor. Trees over 4 inches dbh declined in vigor as the density increased above 16 trees/acre. In dense stands other factors such as previous fire history and grass cover were over-riding factors which affected tree improvement.

When the percentage of tree improvement, or lack of improvement, of several stands of known fire history were compared to possible causative factors there was poor relationship to time since the area had burned previous to the La Mesa fire and to fuel loads. However, there was a good relationship between both improvement and decline of foliar classification with the density of living trees left after the fire.

There is good evidence that competition between the fast-growing seeded grasses was important, while an equal percentage of cover of native grasses and forbs had little effect on tree recovery.

The influence of the insect population which invades after fire is an important factor in weakening fire-damaged trees. Fifteen months after the fire 12% of the population showed evidence of insect damage. Over 40% of the viable trees showed effects of invasion as evidenced by the production of large

amounts of pitch. Herman (1954) found that early mortality of severely damaged trees was hastened by beetles. Miller and Patterson (1927) found infestations of beetles increased within the first year after a fire and then returned to the pre-fire levels. This would indicate that subsequent mortality in the population will probably not be caused directly by beetle infestation.

We found no relationship between root burn-outs, or height of scorch to tree recovery. Connaughton (1936) found that shallow-rooted trees were very susceptible to root damage. The friable, volcanic ash soils of Bandelier would generally favor deep rooting. While the above two fire effects are not obvious, the killing of the roots or girdling of the cambium may cause mortality in a small percentage of the population.

The two months immediately following the fire were average or above in precipitation. This helped to prevent an immediate water stress in these damaged trees. However, within the second growing season the precipitation was below average. The climatic regimes within the first few years following a fire are particularly important in the recovery of fire-damaged trees.

After the first 15 months (two growing seasons) following the fire we found that 90% of the trees had remained viable. Over 50% of the viable trees had over 50% of the crown in green condition, indicating a better chance of survival. There was a general trend of better improvement with increasing size class. A similar situation was noted by Cooper (1960). However, some saplings in open stands, which had suffered complete needle

singeing, showed complete canopy regrowth.

Some of the improvement which was observed within the first two growing seasons may be temporary. Improvement may be due to stored nutrients. After a period of time if the leaf to root ratio does not improve additional delayed mortality will occur. Some which are weakened may be more susceptible to windfall. Nevertheless, some of the trees which have only a small portion of the crown remaining may produce cones and be an important seed source for natural regeneration in areas where few trees have a substantial portion of the crown (Rietveld 1976).

A few trees have died after the third growing season. All of these have been in class 4 of foliar damage and ones which showed no improvement in 1977 and 1978. The mortality was 14% of the class 4 trees living in 1978. Their death is evident by the dead needles and in contrast to the balance of the population which are distinctly a healthy green. There is indication that the peak of mortality is past by the end of the third growing season.

Shrub recovery was greatest in stands which had been previously burned approximately two decades before La Mesa fire. These stands were relatively open and shrubs had had time to recover. Poor shrub recovery occurred under opposite conditions. Where tree foliar damage was severe and trunk and upper root systems of shrubs consumed and killed by the ground fire shrub recovery was minimal. (If tree kill was great but shrub bases were not consumed, shrub recovery was abundant.) The second area of low shrub recovery was stands of minimal tree damage

due to low tree density, low fuel loads, and high percentage grass cover which is competitive with shrub growth.

LITERATURE CITED

Connaughton, Charles A. 1936. Fire damage in the ponderosa pine type in Idaho. Forestry 34:46-51.

Cooper, Charles F. 1960. Changes in vegetation, structure, and growth of southwestern pine forests since white settlement. Ecol. Monogr. 30:129-164.

Foxx, Teralene S., and Loren D. Potter. 1978. Fire Ecology at Bandelier National Monument. Final Report, Feb. 1978, National Park Service, Southwest Region, Santa Fe, N.M. 214 p.

Herman, Francis R. 1954. A guide for marking fire-damaged ponderosa pine in the Southwest. USDA For. Serv., Rocky Mt. For. and Range Exp. Stn. Res. Note 13, 4 p. Fort Collins, Colo.

Miller, John M., and J. E. Patterson. 1927. Preliminary studies on the relation of fire injury to bark beetle attack in western yellow pine. J. Agr. Res. 34:597-613.

Rietveld, W. J. 1976. Cone maturation in ponderosa pine foliage scorched by wildfire. USDA For. Serv. Res. Note RM-317. 7 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.